CHEMISTRY IN EVERYDAY LIFE

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OPPORTUNITIES IN CHEMISTRY

BY

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INTRODUCTION

ALL the good chemists that I have ever
known have been full of curiosity. I
was about to say, as full of curiosity as any
old gossip that ever drank tea, but the simile
is not a happy one, for the chemist is after
knowledge, while the gossip wants to impart
rumors. As curious, let us say, as the child
that wants to know what makes the wheels
go round. That is the real quality. And
the chemist must be imaginative: he must
like to think of things he cannot see. Unless
a man can have a good time by himself, just
wondering, and thinking about things, and
guessing out, as best he can, how they happen,
he can have no joy in chemistry.

There's no use in studying chemistry un-
less one has been able to keep his great talent
of curiosity which so many of us lose when we
go to school. The man who does not get a
reaction of delight at finding out what he
wants to know, and does not want to know

so many things that he gets this reaction
pretty often, had better drop the subject.

And I don't care what the reward is, if a
man hates his job he is to be pitied, pitied
because he hasn't the wit to busy himself
with something that he likes to do. If he
likes to work in the open air he should find
a job in the open air, and if he hates the cold
as I do, it is up to him to look for a warm
place. If he likes to think about things,
he had better think about something else
than his own bad luck, for if he persists in
so doing he is likely to conclude that they're
after him ; and when he becomes obsessed
with that idea the doctors shake their heads,
if the case becomes progressive, and decide
that his proper abode is the lunatic asylum.
It is nothing short of tragedy for a man to
hate his job, unless he is so lazy that he hates
any kind of work, in which case any kind of
a job is good enough for him.

We must bring a lot more chemistry into
daily life than we now have, but my observa-
tions lead me to conclude that it is not al-
ways easy to bring it in by the front door.
Chemistry needs to be applied in many
places where nobody wants it—as yet.

The purpose of this little book is to show
how much chemistry is needed in nearly

every walk of life by the man who thinks
about his work. But the last thing on earth
that I want to do is to persuade men gener-
ally to study chemistry in the hope that it
will support them. Let's see if I can make
this more plain. Suppose a young man has
a desirable position in the fire-insurance busi-
ness. Should he give up his berth and study
chemistry with a view to becoming a chem-
ist? Not unless he is one in a million, and
so attached to the subject that he wants to
do nothing else.

But I do urge him to study chemistry to
help him out as a fire-insurance man, because
his very business is the insurance against a
chemical combination of oxygen from the air
with materials. It would help him con-
stantly as an insurance man to be familiar
with the cause and nature of fires. He knows
from experience the familiar things that are
likely to burn, but he is not informed about
unfamiliar things, and without chemistry he
does not know how to inform himself.

The man on a farm is much better off if
he has a working knowledge of chemistry.
He doesn't need to take soil into his labora-
tory every day for testing; in short, his
business in the field has rather to do with
the physiology of plants than with chemistry.

He has, however, the fertilizer problem on his hand every year, and he requires chemical understanding to gain the full advantage of the reports and the work of the agricultural experiment stations which the government has established for his benefit.

A knowledge of chemistry is something like a good wife. It will help a man along in his work, but he must not count on it to support him. It is not fair to ask this of a wife, nor is it quite fair to ask it of chemistry, unless one has the patience and diligence to study, and the kind of mind that grasps the general principles that underlie chemical relations. My message is : Improve yourself by the study in your spare time. Then do not simply lie down on it or expect it to support you until you have so much of the subject under your feet that it becomes your natural support. Remember, please, that we have not yet arrived at the time when chemistry is made as welcome as it should be. It is a good servant, but a poor master except to the man who is himself a master.

E. H.

OPPORTUNITIES IN CHEMISTRY

I

CHEMISTRY EVERYWHERE

LET'S begin by getting acquainted, for there will be no great harm done if I guess wrong about you. The reader always has the privilege of throwing a book out of the window if he doesn't like the way the author talks—unless the book is borrowed. The author, on the other hand, must keep right on talking until the book is finished. If he is somewhat of a gas-bag, like the present writer, he is likely to enjoy it. If it were not for returning soldiers this work would not have been undertaken; so I imagine you to be young, but not a child, and well set up and hearty, and that you have in the way of education what is represented by a couple of years in a high school. I shall not

call for Latin or Greek, but I am taking for
granted that you are on terms of polite
familiarity with the English language. The
reason why I call for this may be explained
by the fact that I am not young, but am gray-
headed and fat, and instead of being mellowed
into that sweet reasonableness which age
occasionally endows, I find myself rather
testy at times, and if I turn a good sentence
I expect the other fellow to have as good a
time over it as I do.

Since confession is said to be good for the
soul I may as well admit also that I have not
contributed any great discovery to the science
of chemistry. I was out of practice for many
years after studying the subject in Zurich,
Switzerland—for in those days we used to
think it impossible to study it at home—and
after making aniline and aniline colors for a
few years in my native city of Albany at a
time when conditions were not favorable to
the industry. Now my occupation is that of
editor of chemical periodicals.

So, having established ourselves on speak-
ing terms, suppose we take a look at the sub-
ject and see what it includes.

Chemistry is in a way the politics of mat-
ter. At election-time the politician burns
Greek fire and makes speeches and hires

brass bands to warm people up and induce them to vote for certain candidates, to vote wet or dry—to do, in short, as he desires them to do. In chemistry we are dealing with materials instead of with people. The chemist tries to make materials behave according to his will.

The subject is enormous; it is preposterously big, and we have only touched the outer edge of it in many places. Baking bread, for instance, is a chemical process, and the largest concerns have not only chemical control in their works, but maintain research laboratories to test out all sorts of improvements and economies in making bread. Making iron and steel is another chemical problem, because first the iron must be separated from the ore, and then the free carbon driven out of it, and yet just the right amount of carbon induced to combine with it and to make the steel hard with more of it, and soft with less of it. Then comes more finessing to induce other metals to fuse with the iron to give the steel the particular qualities desired.

Consider how this subject of chemistry enters into industry where it is least expected. For instance, if a man makes mowing-machines, it may not appear that it would be

worth his while to bother about chemistry—but he can't get away from it. Next to the design of his machine the chemical features of his practice are of leading importance. Every unit of his product should be made of that very material which will provide the best and most enduring service at the lowest cost. It requires a metallurgical chemist to select most of his materials in the first place, and to hold them to quality afterward. The question where the machine will wear out first, or the location of any structural weakness, is likely to be indicated in specially designed laboratory tests, and the faults should be corrected before the machine is put upon the market. Every spring should be made of steel that maintains its resiliency, and the knives should have and hold the best cutting edge that can be afforded, and the rods should be stiff, without being brittle. These qualities are not regulated by the price paid for steel; it often happens that the best is cheap, provided one knows what to specify and what to buy. Paint is another material that requires laboratory control to insure endurance, maximum covering power, quality of shade, and proper cost, combined with protection against rust.

The structural characteristics of different

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steels and the internal structure of paint films are subjects which not many years ago were wholly within the realm of pure theory. They have now become the very foundations of the best practice. Is it not obvious that the man who knows the real nature, and therefore the possibilities and limitations, of his materials is at least a neck ahead in the race of the one who judges quality by the price he pays, or by the recommendation of a man whose interest lies in making a single sale?

It may not seem evident that a street railway system has much of a chemical side to it, yet street railways buy tons of metal of various kinds. Here the metallurgical chemist makes specifications for that which will best serve each purpose. Then deliveries must be tested. Paints and varnishes cut a larger figure than with the mowing-machine man. Important savings are made by buying supplies, such as lubricants, boiler compounds, soap, and cleansing powders, according to actual needs, under specifications— that is, made to order as specified, and in bulk.

Chemical control is needed in the purchase of railway supplies all along the line, and it takes experience and study to maintain this control. This is the way things should be, rather than as they always are.

The purchase of coal by laboratory-determined heat units instead of by name and weight, the analyses of flue gases to tell how much coal is wasted in firing, and the buying of lubricants on specification instead of by prejudice or favor, are economies that are bound to take their place in industry. And these economies are obtained by chemical control.

At first glance no one would think that a dry-goods merchant needs the chemist's aid—but he does. He should know the actual fiber content of samples furnished, since this will avoid error on his part in purchasing, and will provide the only proper basis for his guaranty that his wares are what he represents them to be. If a piece of cloth is guaranteed to be all wool and a yard wide you can verify the width by measuring it with a stick. But why not make sure of the wool by putting a little piece of the fabric into a test-tube with a solution of caustic soda, and heating it over an alcohol-lamp? The wool will dissolve, and the cotton will not. It is easy enough to do, but we haven't got into chemical habits yet, and so we don't do it. And to the man who buys cloth the microscope is as necessary as a saw is to a carpenter, although there are many buyers who do
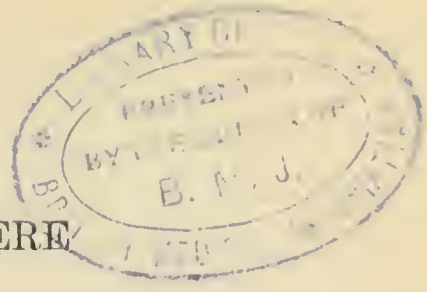
not know how to use it. Buyers often claim to "know by the feel"—and sometimes they get stung. For the chemist trained in textile work it is easy to determine the strength and wearing qualities of fabrics, and the resistance of dyes to bleach, light, mud-stains, and washing. Stockings, for instance, may be analyzed in regard to structure, content, wear and general merit, and they should be so analyzed, but they rarely are. And to save unnecessary expense a dry-goods merchant's supplies . . . paper and other articles of stationery, twine, soap, polish, and the like, should all be determined upon by chemical and physical laboratory tests, and the specifications made for that which will do the work best.

I have copied the foregoing examples loosely from a booklet that I wrote for Messrs. Arthur D. Little, Inc., of Cambridge, Massachusetts, called *Chemistry in Overalls*, for time presses, and these will show as well as others how chemistry touches upon nearly every line of business, and how needful is the chemist in the daily walks of life. We could go on along this line until we made a great, fat book, but we have other things to talk about.

II

THE CHEMICAL VIEW

RETURNING to the politics of matter, we have to deal in chemistry with things that are no more interesting than a list of names of the voters of a city, until we begin to study them. Then we find that they are very interesting. They have ways of their own that are surprising. There are some eighty-odd elements known, and I give you a list of them from *Everyman's Chemistry*, so that later you may know what they are.

THE ELEMENTS

Symbols	Names of Elements	Approx. Atomic Wt. and Valence	Boiling-points in Degrees Cent.	Description
Al	Aluminium	27—3	1800-1	Familiar light metal. Found in clay, feldspar, bauxite; very wide-spread. Melts at 657°.
Sb	Antimony	$120-\begin{smallmatrix}3\\4\\5\end{smallmatrix}$	1440	Silvery-white solid with metallic luster. Usually found with arsenic, which it resembles in many ways. Melts at 629°.

Sym-bols	Names of Elements	Approx. Atomic Wt. and Valence	Boiling-points in Degrees Cent.	Description
A	Argon	40—0	−186	One of the inert gases of the air, of which it forms less than 1 per cent. Makes no combinations.
As	Arsenic	$\begin{smallmatrix}3\\75—4\end{smallmatrix}$		Steel-gray, metal-like substance. Poisonous in all its compounds. Sublimes without melting at about 100°.
Ba	Barium	137—2		A metal of the alkaline earths. Something like calcium. Sulphate used as filler for paper and for paint. Melts at 850°.
Be	Beryllium	9—2		Silvery metal. Found in Beryl. Rare. Behaves like magnesium. Melts above 960°.
Bi	Bismuth	$\begin{smallmatrix}3\\20—4\\5\end{smallmatrix}$	1420	Grayish-white solid, lustrous, same family as As and Sb. Melts at 270°.
B	Boron	11—3		Brown powder. Found as boric acid and aborate of sodium or borax. Does not melt. Volatilizes slightly in electric arc.
Br	Bromine	$\begin{smallmatrix}1\\80—3\\5\\7\end{smallmatrix}$	59	Brown liquid. Volatile. One of the halogens.
Cd	Cadmium	112—2	780	Metal somewhat like tin and zinc. The yellow sulphite is used as a pigment. Melts at 320°.
Cs	Cæsium	133—1	1670	One of the alkali metals. Very rare. Melts at 26°.
Ca	Calcium	40—2		One of the alkali metals. Lime is calcium oxide. Very widespread. Melts at 780°.

Sym-bols	Names of Elements	Approx. Atomic Wt. and Valence	Boiling-points in Degrees Cent.	Description
C	Carbon	12—4		Diamond, graphite, coal. Everything having life contains it. Organic chemistry is chemistry of carbon compounds.
Ce	Cerium	140—3 4		Metal of rare earths. Used in gas mantles and for striking sparks on cigar-lighters. Melts at 623°.
Cl	Chlorine	35.5—1	—33	Greenish gas. Halogen. Very wide-spread in common salt. In rocks everywhere.
Cr	Chromium	52—6	2200	Steel-gray metal used for hardening steel. Salts are used for pigments. Melts at 1520°.
Co	Cobalt	59—3 4		Hard white metal. Very like nickel. Compounds used in pigments. Melts at 1478°.
Cu	Copper	63.5—1 2	2300	Next to iron the metal in greatest use. Melts at 1082°.
Dy	Dysprosium	162.5—3		Hardly known. Found in rare earths.
Er	Erbium	167.5—3		Hardly known. Found in rare earths.
Eu	Europium	152—3		Hardly known. Found in rare earths.
F	Fluorine	19—1	—187	Greenish-yellow gas. One of the halogens. Found in fluorspar and other rocks.
Gd	Gadolinium	157—3		Hardly known. Found in rare earths.
Ga	Gallium	70—3		Rare metal something like Al.
Ge	Germanium	72—2 4		Very rare metal found sometimes with Ag and Pb.
Au	Gold	197—1 3	2530	Almost more important socially than it is chemically. Melts at 1064°.
He	Helium	4—0	—27	Companion of argon. Spectroscope shows

Symbols	Names of Elements	Approx. Atomic Wt. and Valence	Boiling-points in Degrees Cent.	Description
				it in photosphere of the sun. Also found occluded in rocks.
Ho	Holmium	163.5—0		Hardly known.
H	Hydrogen	1—1	—152	Lightest gas. Two-thirds by volume of water. The business end of all acids, and, with oxygen, the business end of bases.
In	Indium	115—3		Rare metal. Same group as Ga.
I	Iodine	127—1	184	Violet-black solid. Found in sea-water and marine products. Heaviest of the halogens.
Ir	Iridium	193—$\frac{2}{3}$ 7		Grayish-white metal, very like platinum. Melts at about 2000°.
Fe	Iron	56—$\frac{2}{3}$	2240	The metal in greatest use. Melts at 1530°.
Kr	Krypton	83—0	—152	An inert gas of the air present to the extent of 0.00005 volumes in 1,000.
La	Lanthanum	139—3		Another element found in the rare earths.
Pb	Lead	209—2 4	1525	Gray metal usually found as sulphide. Poisonous in all combinations. Widely used. Melts at 326°.
Li	Lithium	7—2	1400	An alkali metal, like sodium and potassium. The lightest of metals. Melts at 186°.
Lu	Lutecium	174—3		Found in rare earths.
Mg	Magnesium	24—2	1120	A very light, silvery metal, that would be largely used for its mechanical qualities if it were cheap enough. Melts at 632°.

Symbols	Names of Elements	Approx. Atomic Wt. and Valence	Boiling-points in Degrees Cent.	Description
Mn	Manganese	554— 2 3 6 7	1900	A gray metal, harder than iron, used in iron and steel industry. Melts at 1245°.
Hg	Mercury	200—1 2	357	Silvery liquid. Dissolves and forms amalgams with many metals. Solidifies at —39°.
Mo	Molybdenum	96—2 3 4 5 6		Black metal alloyed with steel to make "high speed" tools. Mo compounds are used in pigments.
Nd	Neodymium	144—		Little known of it. Found in rare earths.
Ne	Neon	20—0	—233	Inert gas of air. 0.015 parts per 1,000 of it in atmosphere.
Ni	Nickel	59—2		Silvery metal, first cousin to cobalt. Used for alloying steel and for nickel - plating Melts at 1452°.
Cb	Niobium	59—3 5		Rare metal found with tantalum. Formerly called columbium, whence the symbol Cb. Melts at 1720°.
Nt	Niton	222—		Name given to radium emanation.
N	Nitrogen	14—3 5	—194	Gas comprising four-fifths of air. Hard to get into combination, but when this is achieved it becomes very lively.
Os	Osmium	191—2 4 6		Like iridium, one of the platinum metals. Melts at about 2300°.
O	Oxygen	16—2	—182	Gas comprising one-fifth of the air. The old Jupiter Maximus of chemistry.

Symbols	Names of Elements	Approx. Atomic Wt. and Valence	Boiling-points in Degrees Cent.	Description
Pd	Palladium	2 106—4 6		Another rare metal of the platinum family. Melts at 1549°.
P	Phosphorus	31—3 5	290	Poisonous white waxy substance, very inflammable, and an amorphous brown powder. Wide-spread in rocks and living things. Melts at 44°.
Pt	Platinum	2 195—4 6	2450	Harder than silver or gold. Does not combine easily with oxygen or with acids. Melts at 1753°.
K	Potassium	39—1	700	Alkali metal, whitish, wax-like substance. Highly inflammable; very wide-spread. Melts at 62°.
Pr	Praseodymium	140—3		Of the rare-earth series.
Ra	Radium	226—2		White metal that turns black in air. Exceedingly rare, radio-active. Melts at about 700°.
Rh	Rhodium	103—		A rare metal of the platinum group. Melts at 1650°.
Rb	Rubidium	85—1	696	A rare alkali metal similar to cæsium. Melts at 38°.
Ru	Ruthenium	102—		A rare metal of the platinum group. Melts at about 2000°.
Sm	Samarium	150—		Of the rare-earth series.
Sc	Scandium	44—3		Very rare. Something like Al.
Se	Selenium	2 79—4 6	688	Gray, metal-like, solid, and amorphous brown powder. Found associated with sulphur. Has properties of metal. Conductivity of electricity is increased in the light. Melts at 170–217°.
Si	Silicon	28—4	about 3000	A brown powder and dark-gray crystals.

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Symbols	Names of Elements	Approx. Atomic Wt. and Valence	Boiling-points in Degrees Cent.	Description
				Constitutes one-fourth of the earth. With O it is sand. Melts at 1500°.
Ag	Silver	108—1	about 1350	White metal known since prehistoric times. Conducts heat and electricity better than copper. Melts at 962°.
Na	Sodium	123—1	877	Alkali metal. Consistency of cheese. Oxidizes on exposure to air. Part of common salt and very widespread. Melts at 97°.
Sr	Strontium	87.5—2		One of the alkaline earth metals with calcium and barium. Sr compounds produce red flames; used for Greek fire. Melts at 800°.
S	Sulphur	32—2 4 6	448	Amorphous yellow powder, yellow crystals, brown, solid and other forms. Very wide-spread. Melts at 103°.
Ta	Tantalum	181—4 5		Gray metal found usually with niobium. Used for electric-lamp filaments. Melts at about 2850°.
Te	Tellurium	127—2 4	1390	Silver-gray with metallic luster. Similar to selenium. Melts at 453°.
Tb	Terbium	159—0		Metal of the rare earths.
Tl	Thallium	204—1 2		Metal, rare, like gallium and indium.
Th	Thorium	232—3 4		Metal of rare earths. Used for incandescent gas mantles with 5 per cent. of cerium. Melting-point very high.
Tm	Thulium	168—		Metal of the rare earths.
Sn	Tin	118—2 4	2275	Ore widely distributed but not plentiful. One of the very

Symbols	Names of Elements	Approx. Atomic Wt. and Valence	Boiling-points in Degrees Cent.	Description
				trickiest of metals. Melts at 231°.
Ti	Tianium	2 48—6		Found nearly everywhere in minute quantities. Alloyed with steel to increase toughness. Melts at 1795°.
W	Tungsten	2 4 184—5 6		Like molybdenum. Uses: electric-light filament for the metal, and solutions of compounds render cotton and other fabrics slow burning. Melts at about 2450°.
U	Uranium	3 4 238—5 6		Related to molybdenum and tungsten. Compounds are used for making fluorescent glass. Melts at about 1500°.
V	Vanadium	2 51—3 4 5		Silvery metal. Head of vanadium family, which includes niobium and tantalum. Increases hardness and malleability of steel. Melts at 1720°.
X	Xenon	130—0	—109	Inert gas. 1,000 parts air contain 0.000006 parts X.
Yb	Ytterbium	172—3		Very rare. Same family as scandium, lanthanum, and yttrium. Related to Al.
Y	Yttrium	89—3		See Ytterbium.
Zn	Zinc	65—2	916	Bluish-white metal. Almost as tricky as tin. Melts at 418°.
Zr	Zirconium	90—4		Rare-earth metal. Used with thorium and cerium. Melting-point very high.

This list is not particularly enlightening. Who cares for scandium or praseodymium? They are, in a way, milestones of chemical advancement. Of these various elements but few are found by themselves in nature; usually they are combined with other elements. The interesting feature about them is that when we get them separated they do not appear to be combinations of any other substances.

There is no general characteristic of elements that makes them different to look at, to feel, or to smell, from chemical compounds. The distinction is a chemical one, you see. While we cannot separate these eighty-odd elements into others, we can separate everything else into two or more of them. Indeed, most of the things we see are combinations of the same dozen or so of them. Air is nearly four-fifths nitrogen, mixed, but not combined, with nearly one-fifth oxygen, a little of a combination of carbon and oxygen which chemists call carbon dioxide and which other folks call carbonic-acid gas, and very much less of other gases. Water is a combination of oxygen and hydrogen, but with all sorts of things in solution. Sand is silicon and oxygen; and clay is aluminium, silicon, and oxygen, with possibly a little iron in it.

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Trees and the green grass are mostly carbon, hydrogen, and oxygen, with some calcium and silicon which we find in the ashes, and there is also combined nitrogen in them as well as in nuts, fruits, and seeds.

It is not very interesting to know of how much oxygen and nitrogen and carbon and chlorine and sulphur, for instance, a substance is composed, except as this may lead to the discovery of something we want to know. Taken by itself, it is about as enlightening as to know that a certain man contains so many pounds of bone, so much skin computed as tanned leather, and so many quarts of blood. But, without going into details, we know that the nitrogen content of nearly all explosives is high. The stuff in the little tubes within us that we call nerves also contains considerable nitrogen. And it is a fair guess that good fighters, men of dynamic energy and quick reactions, such as the late Colonel Roosevelt—and I speak as an ardent admirer—have always been rich in their content of nitrogen. I am not sure that biological chemists will bear me out in this, but it will serve as a parable, if not as a fact, to give an idea of some of the qualities of nitrogen in combination. In short, some elements are of vast importance to human

life, while others we could well forgo, for all practical purposes.

These elements that we have spoken of belong to families under what is known as the Periodic Law, but we shall not discuss that here. Take it for granted, please, that they have certain cousinships, some of which make them very like one another, and others of which would only be observed by the man who works with them. The halogens, for instance, consist of fluorine, chlorine, bromine, and iodine, and I once ventured the remark that they were red-headed and Irish, being in good part Irish myself. Fluorine, with the lightest atomic weight, is like the young lad that you can't hold back. It will eat through glass and combine with hydrogen, for instance, with explosive violence. Chlorine is heavier, and will combine with hydrogen in the light, but not in the dark, while it takes some chemical trickery to make bromine unite with it, and still more to make iodine do the same thing. Fluorine is a light gas, chlorine a heavy one, bromine a fuming liquid, and iodine a solid. There is a certain similarity, and yet a difference in all their compounds, and there is a family resemblance in the way they behave. And if fluorine seems like a young

devil, then iodine reminds us of an old man with a past.

Now the way these elements combine is held to be by means of units that we call atoms. We cannot see these atoms; in smallness they are beyond the microscope, and, like many other things, they are imaginary. But, as old John Dalton discovered, these elements unite with one another in definite proportions, and the units of each element as it unites with one or more others we call its atoms. Since the atoms combine in definite proportions, we can compare their weights, and calling hydrogen, the lightest of all, one, the others are multiples of this.

We used to call the atom the smallest particle imaginable, but we no longer do so. Indeed, much attention is now given to the structure of the atom, and it seems possible that each atom is made up of a complete less-than-microscopic mechanical organization, in which particles infinitely minute revolve about a central nucleus as do planets about a sun. Also it seems possible that the elements differ, one from another, in that their respective atoms are made up of electrons, so called, whirling about a nucleus, but differing in their number, order, and arrangement, just as solar systems are differently

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constituted one from the other. All the atoms of the same element, therefore, are alike. It may be that all the atoms of all the elements are identical in their substance, but different in their structure. Believe me, my friend, we are yet only on the borderland of chemical knowledge; there are still great Americas to discover!

However, the atom of each element is the smallest particle of it that combines, and these atoms have what we might almost call personality. Hydrogen, as we have said, is the lightest, with the weight of 1, and uranium the heaviest, with a weight of 238. One is the lightest gas, the other the heaviest metal. Except in certain inert gases, such as helium, neon, and others, which make no combinations and are known only in a free state, most atoms have what is termed the quality of valence, which may be described as the possession of hooks, or means of attachment, with which they combine with other atoms. Thus hydrogen has one such hook, the halogens each have one, although sometimes bromine gets gay and compromises the whole family with a lot of indefinite relationships. Oxygen has two of these means of attachment. Oxygen forms about one-fifth of the air, and there it is, uncombined.

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Roughly speaking, it is sixteen times as heavy as hydrogen, and, like it, is a colorless, odorless gas. Since then oxygen has two bonds, and hydrogen one, the natural combination of the two would be two atoms of the latter to one of the former, or, as expressed chemically, H_2O, which is water. Any combination of atoms we call a molecule, and so a molecule of water is its smallest particle and is composed of three atoms, two of hydrogen and one of oxygen. But why, you may ask, does the combination of these two gases form a liquid? Of course the liquid state is only a phase of water; as ice it may be a solid, and water also may be a gas or vapor, but as to why it behaves as it does, being a liquid at ordinary temperature, while to liquefy hydrogen and even oxygen takes intense cold and pressure, is more than I know. There is a reason for everything, and it is up to us to find out as much as we can, but the chemical world is full of such problems still to be solved. Certain combinations that are in some respects similar often show similar qualities. For instance, sulphides of metals, by which we mean combinations of metals with sulphur, are likely to be amorphous bodies without mechanical qualities. That is why we do not want

sulphur in coal that is burned under boilers, for the sulphur combines with the iron and ruins the boiler by destroying the steel. Direct combinations of carbon with metals are likely to be hard, whence high-carbon steel is hard steel. Carbide of silicon, CSi, is one of the hardest of substances and is known as carborundum. In certain dyes the predominance of what is called the methyl group, or one atom of carbon with three of hydrogen, and one bond for combining with the rest of the molecule, is apt to give great brilliancy of color, but not to be very fast against light. It is such analogies that help the chemist out and lead him along the road to find out what he is after.

III

OPENINGS IN MANY FIELDS

ALL chemistry starts at the beginning, but it travels along many roads. First we must be familiar with analysis, which is a field by itself. Some men are excellent analysts, while others are bunglers at it. Without caring to confess too much, I shall admit that as an analyst I never excelled. The usual method is to begin with qualitative, and then to proceed to quantitative, which means that the first problem is to ascertain what bodies are present, and the next to ascertain exactly how much of each is there. I have sometimes thought it would be better to begin the other way around and work at quantitative analysis first, simply to establish habits of precision and refinement in laboratory work, and then to take up qualitative investigation in earnest. But the greatest of all arts is teaching, whether chemistry or any other subject, and when we see the splendid young chemists that are

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being turned out in this country we had better not worry the professors. I'd like to worry the young men a little, though. They're young and can stand it. I'd like to pound into them that, aside from studying chemistry and physics and mathematics, they should read history and literature, to get a sense of human reactions into their souls. For every one of us must live his own life, and no matter how small a cog in how big a wheel he may be, he should study the ways of people as a citizen just as, as a chemist, he studies the ways of stuff.

Even as I write this I am hunting for a man to occupy a position in a large establishment. I have found a number who know how to deal with materials, but the difficult feature is to find one who knows how to get along amicably with several hundred men working under him, each of whom has his own life to lead and most of whom will like their job or hate it, according to the nature and disposition of the man placed over them.

One of the best chemists I know had but six lessons in all his life, and he is now over fifty. But nothing could have kept him from the study. He was just made for it and built for it. From earliest boyhood he wanted to follow it, so he gave up a good job

in a jewelry-store for a poor one at less pay in a wholesale drug establishment in the hope that he might get closer to the subject in his work. When his work kept him too much from study he got himself appointed assistant to a milk inspector, and, finally, when he believed he could meet the situation, he hired a room with his savings, fitted it up as a laboratory, hung out a sign . . . and made good!

Doctor Baekeland, of the U. S. Naval Advisory Board, and famous for his inventions, once replied to a man who asked his advice whether his son should study chemistry that "The young men who should study chemistry are those that you can't hinder from studying chemistry." But we're not all built that way. Some of us have to fight our inclinations which lead us to sit still and wait to see what happens. So we have to be led along by the nose for a while, before we get a running start. After the running start is made, however, it is all up to us how much we learn.

We are told in chemistry that there are acids and bases, and that when these combine they produce salts. We know that acids are combinations of elements that give off one or more hydrogen atoms when they

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combine, and that bases give off hydrogen and oxygen, and that when a salt is formed water is produced on the side, so to speak. The charge of the acids is electro-negative, and that of bases electro-positive, but it does not suffice just to know these things; we must make some kind of a picture of them, see them somehow, and get a sense of their parts as they shift around and catch hold of one another.

Generally speaking, acids are likely to have a sour taste, but it is not a good plan to try them out on your tongue. Sulphuric acid, hydrochloric which is also known as muriatic acid, and others are so strong that they will eat right into the flesh, like a red-hot poker. Vinegar, on the other hand, is a weak solution of acetic acid; lemons contain a little citric acid.

Sugar is a very mild base, but caustic potash or caustic soda will eat holes clear through the skin into the flesh. Alcohol is also a mild base, but it isn't sweet, whereas glycerine, also a mild base, is sweetish. There is an electric game going on all the time, and we need to consider the electro-positive and electro-negative charges of these bodies as they wander about in solutions, and hook up to produce things that

are as different from their constituents as water is different from the two gases that produce it. Incidentally we must note right here that a vast number of bodies are neither acids, bases, nor salts. It is this everlasting "Why?" that should be present in the mind of every chemist, just as ambition was present in the mind of Napoleon. The greater the curiosity, under proper direction, the greater the chemist.

There are not so many different kinds of processes, either in the laboratory or in industry. It is the many different ways in which we have to go about these processes to meet the requirements of different materials that makes them so different. We have to dissolve, for instance, which means to get things into solution, and to precipitate, which means to drive them out of it. Then we must filter, which means to separate the filtrate from the solvent. And we must distil, which means to boil and catch the vapors that come over at different temperatures, and thus separate the various bodies that were mixed together. That is the way, for instance, that gasolene is separated from kerosene. We have to evaporate, which at first glance seems simple enough, but which becomes very complex when we have two

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features to consider: that we must not destroy that which is left over after evaporating; and that we must not let the process cost us too much in fuel, time, or other expense. There are large corporations that do nothing but make apparatus of the most diverse sorts to evaporate liquids and to dry things. We must also heat and cool and stir. Then there is the pressure within an apparatus that is likely to play a lively part. But the thousand and one ways in which to do these things, and the headwork to determine when and how to do them, are what make the chemist a success or a failure at his task. He must have imagination.

Chemistry is chemistry, but its applications are so many and so varied that there have developed a great many branches or special fields of study and work. One of the latest and yet one of the most fundamental of these is called *physical chemistry*. This is the borderland between physics and chemistry. If we say that physics is the study of energy and chemistry the study of matter, we shall have said a great deal, but there is room for plenty of explaining afterward. It involves higher mathematics and takes up the study of the behavior of substances in their various gaseous, liquid, and solid

phases, the constitution of the atom and of the molecule—in short, it is the philosophy of chemistry. It has also been called "General Chemistry."

Inorganic chemistry was, as its name implies, originally designed to consider the nature of inert substances that are not parts of, or derived from, the processes of life. But as life processes have been studied, it has been found that they are similar to those of the laboratory, so far as we are able to follow them, and in time the inorganic division has come to cover the study of all except carbon compounds.

Organic chemistry is the study of carbon compounds, and these are of such vast number and variety that they constitute a world in itself. Sulphuric acid, made from sulphur and air, would be considered in inorganic chemistry; acetic acid, which is the acid principle of vinegar and is often the result of fermentation, is treated of in organic chemistry.

Metallurgical chemistry or *metallurgy* treats of the chemistry of metals.

Biological chemistry has to do with processes of fermentation and the changes effected by micro-organisms.

Colloid chemistry is a branch of physical

chemistry, and deals with the properties and behavior of matter in the colloidal state; when particles are of invisible minuteness and yet are aggregations of molecules. We shall discuss the action of soap in washing from the standpoint of colloid chemistry.

Physiological chemistry is explained by its name. It studies what happens to foods as they are digested, all the chemical changes that take place in the bodies of plants and animals, and it is a branch of organic chemistry.

Electrochemistry is that part of applied physical chemistry that has to do with changes wrought by electric currents.

Photochemistry has to do with the reactions caused by light.

In industry we specialize much more closely, and we hear of soap, fats and oils, baking-powder, and all sorts of chemists, but they get their grounding mainly in physical, inorganic, and organic studies. These constitute the basis of it all.

IV

THE GREAT CYCLE OF NATURE

FUELS. Everywhere we need heat, either to warm us, to generate power, or to introduce a chemical reaction, as in baking. It may not be amiss to consider first how we obtain this heat, and where it comes from. Such an examination will prove, too, if I make myself clear enough, how much more in the way of study and invention lies ahead of us than behind us, if we intend to keep up the forward march. It is all very well to strut about, throwing our chests out, and to proclaim what whales of big fellows we are with our modern inventions; but we shouldn't keep up the game too long. When we consider what might be done and what would be done if we only knew more, we look like rather small potatoes.

Let us observe what happens in nature and then compare that with how far short we fall in turning our tricks. We all know of the sun as a source of heat. We know that its

rays are projected through space, carrying radiant heat that is developed as it strikes the earth, as it strikes your body or mine, or the leaves of a plant or tree. In other words, radiated from the sun to the earth through space comes a potential heat that is developed as actual heat when it strikes something. A simple analogy would be your own fist projected through the air at a rapid gait without much of anything happening till it meets the other fellow's eye. Then there is an impact, a concussion, a contusion, and while you experience a certain sense of relief the other experiences a stimulus—or a prostration. But to return to the green leaf, when this receives the impact of the sun's rays something peculiar happens. You may remember our saying that there is always some carbonic-acid gas in the air. We shall soon see how it comes there. Also there is always some water vapor, more in warm air than in cold. The green leaf contains a remarkable apparatus, due to its cells, and to the presence of a substance called chlorophyll which the plant produces as soon as it pushes its way aboveground. With the leaf cells as pressure apparatus, and this chlorophyll as catalyst, or the chemical body that induces the reaction to take place, and with

the heat developed from the sun's rays, molecules of water vapor and molecules of carbonic-acid gas from the air are bunched together to produce sugar. Here we have one of the great chemical processes of nature— the production of sugar out of water and carbonic-acid gas as the raw materials. Water, you remember, is hydrogen and oxygen, and carbon dioxide (or carbonic- acid gas) is carbon and oxygen, and when sugar is made out of them there is some oxygen left over. This excess oxygen is then set free, discharged, and returned to the air. Meanwhile the plant or tree, by means of its sap, carries the sugar on, and, gathering a number of sugar molecules together, bunches them, or, as chemists would put it, polymer- izes them, to starch. This starch is stored away in the seeds as soon as these grow, for the purpose of feeding the new plant of the next generation until it sprouts above the ground and can produce chlorophyll to make sugar and starch for itself in its turn.

The chemical works in every tree and plant, however, have not yet completed their task. That starch is polymerized, or bunched up again, until gums are formed, and finally, to make the structure of the walls of the cells of the trunk and of the leaves and the

branches, a substance called cellulose is re-
quired. This is a very important product,
and we know it in many forms. Cotton, for
example, is nearly pure cellulose. Well, all
cellulose is nothing more than many sugar or
starch molecules bunched into one.

Here you see how important the elements
are, in a way, and yet how little it tells us to
learn that there is such and such a percent-
age of carbon, hydrogen, and oxygen, for in-
stance, present in a body. The ratio is the
same in a given sugar, starch, and cellulose.
And I take it you will also gather from this
that analytical chemistry is not "as easy as
rollin' off a log"!

Now we know that the tree contains a vast
amount of cellulose, and with that under-
standing let us cut it down and burn it for
firewood. If the tree lived ten thousand
years ago, and fell down, and was covered up
it has turned into coal, which is not pure
carbon, but chiefly combinations of carbon
and hydrogen, with less oxygen than the
wood contained. So we may as well burn
the coal. Nature has no interest in time.

We burn the coal to obtain heat, don't we?
Well, heat is motion, but it can be stored,
just as motion can be stored in a watch-
spring that is wound up. When water and

carbonic-acid gas were combined to produce sugar, and when sugar was changed to starch, and the starch to cellulose, it took a vast amount of heat to effect it. All this heat came from the sun. I say, a vast amount of heat, and it was no less than that, but it was spread over a great deal of surface—over all the leaves of the tree. Let us be sure that we are clear about this. Suppose we put a 150-pound man upon a platform. Then, no matter how small or how large the platform, we have on it a downward pressure of 150 pounds. Now suppose we place upon it a thousand men of the same weight. That would make 150,000 pounds. With these thousand men still upon it, suppose we balance our platform on a single strong pole. The pole will be exerting a downward pressure of 150,000 pounds beyond its own weight and that of the platform, all in one place. Now if you measure the surface of every leaf of the tree, and compute the time the sun's rays have been impinging upon them, it soon becomes clear that the aggregate of all the heat used in the growth of the tree for fifty years, if developed, and confined in one place within half an hour, say, would be enough to fry a young elephant!

When we burn coal first we heat it, usually

by burning loose stuff like cellulose from wood, the particles of which are reached more easily by the air, until the reaction is started. And what is this reaction? It is the very opposite of that which happened when the tree grew. Then we started with water and carbon dioxide and heat from the sun; lots of heat from the sun gathered upon the surface of a great number of leaves. And in these processes of growth oxygen was given back to the air. When we burn wood or coal we induce oxygen from the air to combine with the carbon and the hydrogen to form what? Why, to form carbon dioxide and water! These are the main constituents of smoke. Right around in a ring again, you see. And, just as the first reaction required heat to make it take place—starting with water and carbon dioxide and carrying these through to cellulose—so, in the second reaction, the heat is given off when we burn our stuff back to carbon dioxide and water again. And whereas in the first reaction oxygen was given off, so is it taken on again in the second. A complete cycle, you observe, even if it does take ten thousand years to bring it about. Nature isn't at all interested in time; nature can afford to wait a million years, if need be, for its opportunity. And we cannot!

Speaking of smoke, it is well to remember that it contains other bodies besides carbon dioxide and water. White smoke is due to steam, but black smoke is due to soot, to particles of carbon thrown out in the burning process, because there was not heat enough or air enough on the spot to make the combination to carbon dioxide. Then, too, for lack of sufficient air, another gas is formed, called carbon monoxide, the molecule of which comprises one atom each of carbon and oxygen. This is the choking poison gas that is in chimneys, or that arises from a brazier of charcoal that kills people when burned within an inclosed room. The other gases of the air besides oxygen remain unaffected by the fire; they pass on, without going into combination, despite the heat.

Dr. Giacomo Ciamician is professor of chemistry at the University of Bologna in Italy. When in New York in 1912 he made a famous speech in the Great Hall of the City College. "Why," he asked, "use only the fossil energy of the sun—for that is what we do when we burn coal! Why should not man use sun-power direct, as do plants and trees?" To catch this radiant energy of the sun and to turn it to account it would be necessary to devise an apparatus, a practical

apparatus, corresponding to the leaves of tree and plant. But Professor Ciamician insisted that what plants and trees do we also should be able to accomplish, and he affirmed his belief that some day the riddle will be solved and the requisite apparatus perfected. Then he made a few calculations as to what may happen when this end shall have been attained. Using the sun for only six hours out of the twenty-four, and making generous allowances for waste, he concluded that the sun would deliver in energy taken direct from its rays, instead of by our present roundabout fashion of recovering it by burning coal, the daily power value of 2,500 tons of coal per square mile. We mine in the United States about six hundred *million* tons of coal every year. The Desert of Sahara receives every day in solar energy the equivalent of six *billion* tons of coal!

He then showed a long list of chemical processes which indicate progress and study toward what he called "The Day of Light" . . . toward this use of sun-power. He prophesied that in time tropical countries will be thickly populated; that on their now arid lands there will spring up industrial colonies, unmarred by smoke or smoke-stacks, while over the plains about them vast forests of

glass will rise, and glass buildings will be seen everywhere. Inside these will take place those processes that are still the guarded secret of trees and grass, but with these once mastered, added the professor, human industry will drive them far harder than does nature, because mankind is always in a hurry, while nature is not. So, soon it may not be necessary to dig coal, or to worry about the supply or price of it. With such enlightenment, when it comes, we shall not require fuel so long as the sun shines. And when the sun ceases to shine we shall not need anything at all!

Whenever we get to fancying that we are as clever, able, or as wise as anybody need be, it is worth while to take a glance at a tree, at any old tree, even the scraggly back-yard runt with the wash hung out on it to dry, and say to ourselves that when we can turn the little trick that that tree does daily, it will be plenty of time to perk up and grow chesty!

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V

WHAT FUEL IS

WE know that when we burn wood or coal we are setting free heat that was originally contributed by the sun. Now fuels are solid, liquid, and gaseous, and the same rule holds good for liquid and gaseous fuels as for solid—the heat released by burning them had its source in the sun. Or, rather, it seems to be so, for the origin of petroleum and of natural gas is still a matter of theory, and there are a great many theories about it. Petroleum is not a single chemical body; it is a great number of combinations of carbon with hydrogen, and these sometimes also contain sulphur and again nitrogen. Natural gas is mostly methane, a combination of one atom of carbon to four of hydrogen (CH_4, as the chemists write it), and crude petroleum contains a whole series of hydrocarbons, as these combinations are called, that include gasolene, kerosene, heavy oils, and waxes.

No matter what the form of the fuel, in

burning we must arrange it so that plenty of air can get to it. Gas is blown in with the air, liquid is blown in with the air, and coal is spread over the burning surface with air coming up from below. Burning fuel by letting the air combine with it seems simple enough, but in reality it is a great art to obtain from it the utmost amount of heat available, nor have we yet arrived at the best methods. For instance, the air is, roughly, four-fifths nitrogen and one-fifth oxygen. In its free state the nitrogen passes right on. Whether we heat it or leave it cold, it will not combine. And of course it holds the fire back for this reason: imagine the oxygen molecules (for oxygen atoms do not exist in a free state; they pair up with other oxygen atoms in twos, and nitrogen atoms do likewise)—imagine the oxygen molecules, no matter how small they are, flying about like bees. The heat drives the atoms apart, leaving them ready to combine with carbon and hydrogen atoms which were also combined, but which also have been loosened up by the heat. These combinations, when effected, give off a great deal more heat. So, if we imagine the nitrogen molecules to be another species of exceedingly small insects that do not sting or combine, it is

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evident that, being present in the air in four times the number of the stinging bees, or combining molecules of oxygen, they are very much in the way.

If we were to separate the oxygen from the nitrogen in the air, and let only oxygen into the fireplace, we should have a blaze so hot that we could not well manage it. It would warp the grate bars and boiler plates and consume the coal in short order. We can separate these two gases, for instance, by making liquid air and then distilling off first the oxygen, and then the nitrogen, and collecting them in different chambers. Liquid oxygen boils at −182° Centigrade, and liquid nitrogen at −194°. Translated into Fahrenheit that is 295° below zero for oxygen, and 317° below zero for nitrogen. Rather low boiling-points when you come to think of it. But the process is too expensive for burning fuel, and we are not equipped to handle the great heat that would be produced. We are not used to it, and about the hardest thing on earth is to induce people to do things in a way they are not used to doing them, no matter how great the advantage.

There is another method of burning coal that is coming along as fast as inventions

can meet it. If it is ground up to a very fine powder, and blown into a fireplace with just the right amount of compressed air, it stands to reason that we shall burn it completely to carbon dioxide and water with no soot, and with the greatest amount of heat where the combination takes place, and that only the ash will be left over. Ash and clinker are minerals like powdered rock and glass that have been contained in the coal. In this method two difficulties have not yet been completely conquered, one being the disposition of the ash, the other that under boilers, for instance, the heat developed in one spot is so intense as to be likely to warp the boiler plates. It is in general use in cement mills, where great heat is desired to make the cement clinker, and it is being tried out in many other applications. Good men are at work on the problem.

There's another fuel, immense quantities of which are to be found in this country and in Canada, but which has not yet come into general use, and that is peat. Peat is young coal, coal in the making, and it is found to contain much less oxygen than wood. It is in wide use in western Europe, and in Ireland, where about one-tenth of the area is covered by peat-bogs. The

older the bog the darker its color, and the more the peat resembles coal. As the clods are cut from the ground they contain a large amount, sometimes as much as nine-tenths of their own weight, of water, and while some of this may be expelled by pressing, much still remains, owing to the jelly-like character of the substance. Better results are said to be obtained by heating these clods before the pressure is applied. A great deal of peat is merely cut and dried in the sun.

Lignite, or brown coal, represents a greater age than peat. It contains about 35 per cent. of water, which, on air-drying, falls to about 15 per cent. The next stage is bituminous coal, which is the most important fuel there is, and finally we have anthracite, which is the oldest and hardest coal. Charcoal is made from wood by two methods. The old way is to pile the wood into large, circular heaps, leaving a flue from the outside to the center near the bottom, and an upright flue at the center, and then to cover the whole, except the inlet of the side flue, and the outlet of the top flue, with earth. Then a fire is started in the hole at the side, and just enough vent left at the top for the gases to escape. The light hydrocarbons are driven

off by the heat, and they burn as they escape from the hole at the top. When these escaping gases cease to burn with a luminous flame the two holes are plugged up with earth, and the fire dies out. There remains about 25 per cent. of the weight of the air-dried wood as charcoal. That is the old way. Everything but the charcoal is lost.

Now let us put science to work and see what happens. Instead of burning part of the wood we put it into a closed retort, like a steam-boiler, and heat it from the outside. We save the fumes, running them through cooled pipes, and from hard wood get, not only the charcoal, but wood alcohol. We also get, by adding the base, acetate of lime, from which acetic acid is produced. This, you may remember, is the acid of vinegar, and is largely used in the industries. From soft or resinous wood we get, besides the charcoal, turpentine, wood tar, also some acid and alcohol, though less than from hard wood. Pine oil is another product for which there is an increasing use. This method of making valuable products, including charcoal, from wood waste is a growing industry. Still another important addition to the manufacture of lumber is the production of paper pulp from wood waste. That is coming along,

too. We have been wasting two-thirds of nearly every tree cut for lumber, and we must get over doing that.

The same thing holds good in burning coal—we can burn it and waste a great deal of the heat by burning it as coal, or we can put the coal in a closed retort and heat it from the outside. Then we get gas from which some of the heat has been lost in the making, and coke and tar. But while some of the heat has been lost in making gas, it is likely in the end to be more economical to burn gas than coal, provided the cost of delivering the gas through pipes can be brought down to a reasonable figure. It certainly should be cheaper to run gas through great mains than to carry coal on railroads. Then, too, there are all the low-grade coals that may be used for gas, this gas being made at the mouths of the mines and brought by pipes to cities and villages. We may expect to see this, if we live long enough. And there will remain the coke and the tar.

The tar contains oils, light and heavy, used in making colors and explosives, also for solvents, motor-fuel, the pitch for roofs and roads, carbolic acid, and ammonia for fertilizer. And, while the coke from low-

grade coal isn't good for much, there is a chance for chemists to work over it and find a way to make it useful.

Still another thing coming along is to make gas at the mine, in gas retorts, and then work it to operate gas-engines, and with these to operate dynamos, and so produce electricity which may be transported at high tension on wires for 250 miles economically. In theory the gas-engines are cheaper to operate than steam-engines. There is one step less in getting the energy out of them, because in the former we explode the gas with air, and that gives us the energy in the cylinders. With steam we burn the gas to boil the water which, as steam, expands in the cylinders. But steam-engines are simpler; we know them better, have worked with them longer, and not only do they cost less to build and install, but they are less liable to get out of order. But it will only be a matter of time, I think, before the gas-engines in big units will be seen as often as the steam-engine.

The most wasteful method of producing power in large units is the railway steam-locomotive. Whenever I see one I am likely to think that we ought to do better than that. At the same time I should have to

admit that I do not know how to improve upon it!

Now let us take another look into the future and imagine peat-bogs and lignite mines getting out fuel and turning heat into electric energy on the spot, and serving the district within 250 miles with electric currents for lighting, cooking, and power for factories and railways. The time should come when we may do away with ugly factories, smoke-stacks and grimy smoke, and do our manufacturing in pleasant places with agreeable surroundings. These things can come to pass, and I honestly believe they will come to pass.

VI

CHEMICAL SPECTACLES

WE have talked longer and said less about fuels than I had intended. But if we can get the chemical picture into our eyes—the innumerable little molecules floating about, breaking up and recombining so fast that they get red-hot over it—we shall have made some advance, anyway.

Now let's consider soils and what happens in them. About the busiest part of the earth is earth. In the first place, earth is of various sorts, being chiefly either sand in which silicon predominates, because sand comes from the weathering of quartz, and quartz is silicon dioxide—one atom of silicon to two of oxygen in the molecule—and clay. Clay is derived from volcanic rocks, and it is chiefly aluminium silicate, or a combination of aluminium, silicon, and oxygen. I said chiefly, but there are innumerable other substances also. The general characteristics of a clay soil are its fine texture and the ad-

hesion of its particles. It absorbs moisture from the air, and water comes up with it from below by a process called capillary attraction. If worked while it is wet it becomes hard, and it retains moisture obstinately. In a sandy soil the particles do not adhere to one another; very little moisture is attracted from the air, and water percolates through easily, thus washing out perfectly good fertilizer that has been placed there. This sandy soil absorbs and retains heat well; it is dry and warm, and it will not bake. It will draw about two-thirds as much water from below as clay. A clay soil is likely to be wet and cold. A soil that is all sand or all clay is not good for much, as a rule. A mixture of the two is better.

The soil water is constantly in motion. When it rains the water sinks into the soil. It has some oxygen dissolved in it, and it picks up and dissolves carbonic-acid gas and compounds of nitrogen and carries them down into the earth. When the rain ceases the water begins to evaporate, and as it does this it brings up various bodies in solution. These the roots of plants pick up and use for growth.

We discussed how the leaves collect carbon dioxide and moisture to make sugar, and

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from that cellulose for the walls of their cells. But the plant needs a great deal more than cellulose. It needs iron to color its leaves green, for without this they are white. There is always iron in the soil. It is compounds of iron that make clay red or blue. A plant also needs silicon to give stiffness to stalks and branches, and it needs potash and phosphorus compounds and nitrogen in combination. The plant is very particular, and will not stand substitutions. For instance, we may say that the two elements, sodium and potassium, are closely related, and behave very much alike in their reactions. In making medicines we can sometimes substitute soda for potash without greatly changing the effect. But we can't change soda for potash with plants. Plants just won't have it! Lime also is wanted, and magnesia, and these are more or less present in the soil.

So we have the soil water constantly moving up and down, like a tide, passing the roots which are spread out to catch it with what it has in solution. Soils have the power to draw water up from as far down as six or seven feet underneath the surface by this capillary attraction. Sometimes in a soil rich in clay the soil water will carry very finely divided particles of clay in suspension

to the surface, where it evaporates, and as, of course, it can't carry the clay with it into the air, clay is left as a thin top layer upon the earth. Then the heat and winds dry this crust, and it bakes there, which is a bad thing, because it is not porous. The water a few inches below remains stationary, heat and gases are excluded, the activity in the earth decreases, and the earth becomes cold. The chemical processes necessary to provide for the plant are slowed down so much that the plant does not grow. The best remedy for this is lime, not because the soil is acid, but rather because the lime clots the clay into little granules, much as milk is clotted if vinegar is poured into it. This keeps the soil porous, and hinders the formation of that impervious sheet of clay. In addition to all the chemical liveliness there are worms that keep the soil in a state of fineness which is a great aid to chemical activity.

Added to all this there are myriads of micro-organisms present, some of which are of great help, and others of which retard plant life. There is one kind that gets busy with leguminous plants, such as clover, cowpeas, beans, and other varieties that get the nitrogen of the air into combination in little

nodules on the roots and stems, thus providing the means of growth, since all living things require nitrogen in combination. There is plenty of nitrogen in the air, but it will not combine except under certain conditions, such as by means of an electric spark or a stroke of lightning. The art of fixing nitrogen, or of getting it to combine, has only been developed of late, but no method so simple as that of micro-organisms has been discovered. How they do it remains a secret still.

Another body contained in soils is decayed vegetable matter in a state of very fine division, and this again is of value to the plants. It is called humus. All through chemistry we find that the size of particles or grains of materials employed has a great bearing on what takes place, whether it be in the factory, the laboratory, or in the nutrition of plants. It stands to reason that materials should behave differently in a very finely divided state, because the smaller the particles the greater the area of surface presented. For instance, when a woman is baking bread, if she puts the whole batch of dough into the oven in the form of one huge loaf, this will not have anything like the total surface that would be presented by ten small

loaves of the same batch. There is more crust on the ten small loaves than on the one big one. Chemical attack takes place upon the surface of the particles.

The entire subject of what takes place with particles in a state of exceedingly fine subdivision is known as colloid chemistry, and it is a remarkably interesting field.

Why is it, then, if plants are so particular, that they have such bad taste as to like manure, dead fish, and "guano" that smells to high heaven? That's a fair question.

In the first place, as we have already re-marked, nature is not in any hurry at all. And these trees and plants have no conven-tions; they do not concern themselves with the origin of the materials they need. Animal manure contains such parts of the hay and grain as the animals did not require for their sustenance, and it is in a very finely divided state. Mixed with straw and al-lowed to rot or ferment, it works into a con-dition most favorable to plant growth. The smell does not count, so far as we know, but smell is something that has hardly been studied. It is a vast, open field, with only the initial steps taken as to the chemical nature of things that produce odors. We are not practical about smells; a good dog could

give us clubs and spades and still beat us at telling what smells mean.

The three things that plants are most likely to need are combined nitrogen, phosphoric-acid salts, and potash. Unless the condition of the soil is favorable, the value of fertilizers goes down; but, granted good conditions, we need to add these three things for heavy crops. The neatest way to get nitrogen into combination in the soil is to plant clover or cow-peas, and turn them under, because the micro-organisms fix the nitrogen of the air into combination upon them. The objection is the time this takes. Stable manure contains combined nitrogen, and so do dried blood, tankage, guano, and cotton-seed meal. Nitrate of soda and sulphate of ammonium contain it, and in these forms it is usually found in manufactured fertilizers. Although ammonia, which is a gas consisting of three atoms of hydrogen to one of nitrogen in the molecule, is not used in a free state in fertilizers, the nitrogen is usually "computed as ammonia" when the content is given.

Phosphoric acid is used combined with lime, but some of these combinations are more valuable than others. If phosphate rock is ground and treated with sulphuric

acid it becomes more soluble, and as such it is known as "acid phosphate." Dried and acidulated bone is another source of phosphorus for plants. Just because bone and tankage and the like smell pretty high some farmers are of opinion that the more the fertilizer stinks the better it must be. I repeat, there does not seem to be any value in bad smells in fertilizers. Nevertheless, what is wanted is likely to be supplied; and I recall types of fertilizers, years ago, that brought a special high price just because they smelled bad enough to curl up the nose of an owl. The thrifty dealer knew what was wanted, got a chemist to give him some materials that smelled strong enough to drive away ghosts, poured these on his "special fertilizer," and charged double. The potash was formerly brought from Germany. We have developed the manufacture of some potash in this country as a by-product of the cement industry, from iron blast furnaces, and from deposits in certain lakes in the West. There are large deposits in Alsace which will probably soon be coming in, and some has been found in Spain. These three kinds of chemical bodies used in fertilizers, the combined nitrogen, the phosphoric-acid salts, and the potash, are merely an extra supply

of some things that plants take out. The plants could not grow on them alone. For their growth they also need the finely divided condition of the soil, the active life of the micro-organisms, the humble tributes of the worms, the vast complexity of organic bodies found in the humus, and the slow surge of the water up and down.

We may find rest under the sod, but it is nevertheless a very lively place.

VII

SOME INTERESTING CHEMICAL PROCESSES

ONE of the most interesting things one meets in chemistry is called catalysis, and this shows especially how like are people to the little molecules. It shows something very like personality among such inanimate things as salts or metals. Let us take two bodies that, according to the usual ways of things, should combine when we bring them together. But they don't. Then we dissolve them together and heat them and shake them up and still nothing happens. Finally we add a very small amount of a foreign body that, so far as we can see, has no relation to either of the bodies we have in solution or to the one we are after. It may be a surprisingly small amount of powdered metal of one kind or another. As soon as this comes into contact with the others the solution froths up and the reaction we are after takes place. We call that influential stuff that caused all the commotion and that we are

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likely to find all unchanged at the bottom of the beaker, a catalyst or catalyzer.

Now observe the analogy. Suppose a number of us are sitting around a table on a sour, rainy day. We are a committee, and we want to put something through, but none of us knows enough, and nobody can think of the right measure to adopt. All told we are a dull, solemn, stupid lot. Then in comes some other fellow who sits down, tells a couple of stories that put us in a good humor, and in a few minutes has us all talking. Soon we begin to think and exchange ideas, and in half an hour's time we have accomplished exactly what we came there for; we know exactly what to do, and have resolved upon it. It was that last man who set us going. While he didn't know any more than we did when he arrived, there was something about him that made us all alive and started us up. That man is what in chemistry we should call a catalyst. He did not tell us what to do, nor did he himself do anything but just sit there and talk. But as a result of his being there we got busy and did what we had been unable to do before. Chemistry is full of that sort of thing.

Now let us consider sulphuric acid, which is used everywhere. To make fertilizer

millions of tons of it are consumed every year, chiefly to render phosphate rock soluble. It is required to purify petroleum; for instance, for pickling iron and steel, to make explosives, and all sorts of things. A vast number of manufactured articles have met sulphuric acid at some point or another in their history. It is made up of two parts: a combination of sulphur and oxygen on the one hand, and water on the other, all combined into one body. As soon as that is made it will draw on water from the air, and if we don't look out it will draw on so much that it becomes weak, whereas the strong concentrated acid is what is often wanted, and which brings the better price.

If we burn sulphur or roast a sulphurous ore, oxygen combines with sulphur in the relation of two to one, or, as chemists express it, SO_2. That is the choking gas we smell when sulphur burns. Everybody was familiar with it when we used the old brimstone matches. But that gas is not what we want. We want another atom of oxygen in that molecule; we want it to be SO_3 instead of SO_2. Then instead of being a gas at ordinary temperature it will be a white crystalline substance that will draw on water with the development of heat, and that is one of the

most powerful acids known. The question is, how to get the extra atom of oxygen into combination. It will not readily happen by itself; we must find something that will introduce the oxygen to the SO_2 and make them combine. Combinations of oxygen and nitrogen will effect this, and so, into the great leaden chambers they bring the gases through a mixing device called the Glover tower. Steam is let into the leaden chambers and the product goes out through another tower at the end. Then we have the acid. The result is not a very strong acid which contains about 65 per cent. of it mixed with water, and when stronger is needed it is boiled down in pans made of high silicon iron.

It was a good deal of trouble to get the SO_3 without water enough to make a complete acid, and yet SO_3, or oleum, as it is called, mixed with 100 per cent. acid, is needed in some chemical operations. When it was discovered in Germany how to make indigo out of coal-tar products instead of from the indigo-plant, it was found that immense quantities of this oleum would be needed, and accordingly they set to work to find some better way to make it; to find another catalyst. Platinum they found would do it, and later developments provided for

platinized asbestos, against which a stream of sulphur gas will take on the extra oxygen from the air and become SO_3. There are many details to the processes of making sulphuric acid, or oil of vitriol, as it is often called; but we shall not discuss them here.

Speaking of indigo, which is used in vast quantities here and elsewhere—we used 13,-000,000 pounds annually before the war—it was a great turn to make it out of coal-tar products. It was a romance and a tragedy, this discovery. When the whole process was worked out it took years to do it and cost millions of dollars before a cent of return came in. Then thousands of acres of indigo land in India, China, Japan, and elsewhere had to be put to other tillage. It was as disastrous for the indigo-planters as it would be for our cotton-planters were some one to find a substitute for cotton that was cheaper and better, so that no more would be wanted.

While engaged in working out a process that would be cheap enough to succeed in practice, a chemist was engaged in the effort to oxidize naphthalene, which is that white crystalline stuff obtained from tar that we buy at any apothecary's in the form of moth balls. He wanted to carry it over from

naphthalene to phthalic anhydride, and for
this purpose he had everything ready. It
was all in a dish which he was heating from
underneath by a blue gas flame—but noth-
ing happened. He watched the temperature
carefully as it rose by means of a thermom-
eter with the bulb stuck into the hot mass
—but still nothing happened. He had tried
it before without success, but each time he
changed the conditions slightly, because there
was no reason why that reaction should not
take place, so far as he could see, except
that it didn't. Finally his thermometer
broke, whereupon he began to swear. That
was a nuisance! And the quicksilver from
the bulb and tube had run into his mixture.
He was just about to turn off the gas and
start all over again when he noticed some-
thing happening in the dish. The mixture
began to froth up and stir around of its own
accord, and, before he realized it, the very
thing he wanted had taken place before his
eyes. Mercury was the catalyst. After the
reaction was over the mercury was at the
bottom of the dish, all unconcerned, but the
whole first step in the industrial manufacture
of indigo from tar products was revealed.

There are a great many reactions of the
same kind, and inside our bodies we keep

producing what are called enzymes that change the food we eat to make it digestible, in the first place, and, as the processes continue, to affect that which is taken up to renew or to build tissues as well as that which is discarded. Saliva, otherwise known as spit, is a very important enzyme. We have a whole string of little chemical factories within us that work together under remarkable control, and when this control is out of working order we sicken and die. It's beyond my comprehension to understand how we manage to live as long as we do!

VIII

FERMENTS

IN chemical practice it is a good thing to
let Nature do as much as she will. And
one of Nature's most useful agencies is known
by the general term of micro-organisms—
things, in short, that it takes the microscope
to distinguish. A popular name for them is
germs. They are divided into three general
classes: yeasts, molds, and bacteria. Some
of them are so small that we cannot separate
them by any filter known, while others we
can observe with the naked eye. They are
of innumerable variety; many of them cause
disease, and others are very useful and bene-
ficial. Roughly speaking, we may say that
yeasts resemble microscopic vines; molds
are like microscopic moss, and bacteria are
very small rods and spheres. They are not
animals; they are plants, and mostly plants
of a low order. For their growth and devel-
opment they need carbon, nitrogen, oxygen,
phosphorus, and calcium, all in combina-

tion, and water. But they are very particular as to the exact combinations needed, and many of them will only thrive and reproduce their kind—usually by division—under peculiar conditions. The typhoid-fever bacillus, for instance, is usually quiet enough until it reaches a certain place in the human intestines. If it can find lodgment there it proceeds to establish a colony, and the products it throws off as it grows poison us.

The most familiar yeasts are those used by distillers, brewers, wine-makers, and in bread-making. Yeasts are, however, of many varieties, although we shall have to neglect the many differences. The brewer is exceedingly particular about his strain of yeast, and yet brewer's yeast is not very good for bread-making.

The business of these brewers', distillers', and bakers' yeasts is to turn sugar into ethyl alcohol and carbonic-acid gas—and ethyl alcohol is that chemical body that has got into politics. It is the alcohol of beer and whisky and wine, sometimes called old John Barleycorn. Yeast will not grow well in a solution of pure sugar and water; it must have nitrogen in combination, and other materials in solution. Then, as the minute vines grow they produce two enzymes, one

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of which oozes out of the cells and makes
the sugar in solution fermentable. Some
sugars will ferment easily, and some will not,
but we shall have to let the statement go
at that, leaving the why of it unanswered.
Then these fermentable sugars ooze in,
through the yeast cells, and here they meet
the second enzyme, where the change to
alcohol and carbon dioxide takes place. In
making beer it is necessary to add malt,
which contains a diastase, and the business
of a diastase is to convert starch into sugar.
That is because the remainder of the malt,
and the corn, and the rice, and whatever is
used in the beer, contains a great deal of
starch, but very little sugar. Now let's re-
member that the reason starch is there is be-
cause these grains are seeds, and the original
plants stored the starch in the seeds to feed
the young plants until they were well enough
organized to go into the business of making
sugar and starch and cellulose for themselves.

In making bread the housewife or the baker
puts sugar into the dough in order to give
the yeast a chance to ferment it. The flour
is mainly starch ground from the seeds of
wheat. It makes a sticky mass with water,
but the yeast lives and grows in it. Lately
a food for yeast has been discovered which

makes it thrive still better, and causes less yeast and less sugar to be necessary in the dough. After the dough is made the batch is set aside in a warm place to "raise," and here is what happens: The yeast ferments the sugar that comes into its way to alcohol and carbon dioxide. That carbon dioxide is there, and it can't get out, but, being in a warm place, it expands and makes little holes in the dough. That is what makes the dough rise; it was solid before, but with those little holes forced by the carbonic-acid gas of course it takes up more room. Then it goes into the oven. The sugar on the outside loses water and becomes caramel, while the carbon dioxide and alcohol are driven out by the heat of the oven as the dough hardens to bread.

Whenever a chemical reaction takes place on a large scale there is usually a whole series of reactions besides those wanted. Sometimes they are important, and sometimes they are a great nuisance. For instance, in making alcohol from corn or molasses, or from substances containing starch or sugar, there are by-products. Fusel oil used to be a great nuisance in alcohol when the spirits were intended for drink, and I should not advise anybody to get gay with it; but so

many uses have been found for this liquid, termed amyl alcohol in chemistry, that its price has gone 'way above the so-called grain or ethyl alcohol. Fusel oil, or, rather, amyl alcohol, is used to make amyl acetate for the celluloid industry, for airplane dope, and in manufacturing perfumery, and it is in demand for a lot of other uses. But it is not fermented from sugar; it is a product of proteins which contain nitrogen, and which are formed in the true germs in seeds and in all things having what we call life. The direct fermentation in quantity of fusel oil from protein substances has not been developed in industry as yet, so far as I am aware. Glycerin also is produced on the side in the fermentation of sugar to alcohol, but only in small quantities.

Molds are coming into use often to change starch to sugar in fermenting. They were largely introduced by Doctor Takamine, a famous chemist, and one of the best-known and most-beloved men of Japanese birth living in this country. A great industrial alcohol establishment in France uses potatoes as its raw material, and, potatoes being chiefly starch and water, a diastase is necessary. In these works, instead of using malt a mold is used to convert the starch to sugar.

We mustn't think that under bone-dry prohibition the production of alcohol will cease. It's a great pity it does so much harm, because it is one of the most useful bodies known to chemistry. It is a grand solvent, for dissolving gums and the like, it is an excellent disinfectant, and, fortunately, it is possible to mix it with things that render it undrinkable.

Another time-honored use of micro-organisms is in production of cheese, which is accomplished by molds. There is, however, a long list of other useful bodies, such as acetone, lactic acid, butyric acid, and other compounds, formed by the action of these micro-organisms. And the end is not yet. Every month or so we learn of the production of something needed or interesting by the action of bacteria.

An idea of the infinite variety of these organisms may be gained from the fact that whenever we see putrefaction or rotting of any kind going on, they are present.

The late Dr. Ernest G. Genoud, who was well informed on the subject, proposed that instead of burning garbage we should ferment it and get good gas to burn for lighting and heat out of it. This he thought to be feasible.

IX

SOAP

TO understand what soap is we must first consider fats and oils. The oils in question are animal and vegetable oils, not petroleum bodies. Petroleum bodies are in the main combinations of carbon and hydrogen; fats and oils are combinations principally of carbon, hydrogen, and oxygen. They are combinations of what are known as fatty acids with glycerin. The acids in solid fats have more hydrogen in them in proportion than do those of oils. So if we want to turn an oil into a hard fat we can do it by bringing hydrogen gas into contact with it in the presence of very little particles of nickel. Nickel is the catalyst, and introduces the hydrogen into the oil molecules, and by this means, under proper heat and pressure control, we can turn cotton-seed or olive or peanut oil into hard fats. Fish oil, which we should not recommend to anybody with a

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nose left on him for a salad oil, becomes an odorless, wholesome fat when hydrogenated; that is, when hydrogen has been introduced into the molecule in this manner. The base in the molecule, the glycerin, is not changed in the process.

Now in fats and oils we have these fatty acids combined with glycerin, which is a weak base. Suppose we then put into them a strong alkali such as caustic soda and boil. The strong base will drive out the weaker one and take its place in the molecule; and when we do this with alkalis and fats we get soaps. If we use caustic soda we get hard soap; with caustic potash the soap is soft. But after boiling we have a mixture of soap and glycerin all dissolved in the water, and we want to separate them, so we put in some salt, ordinary cooking salt, which curdles the soap so that it floats in flakes on the surface.

Soap is soap, and there is the outline of the process of soap-making in theory. In practice there are a great many steps, especially in finishing the soap, but that isn't our business now.

Glycerin was almost a waste product until Alfred Nobel, a Swede, in 1863 discovered that by mixing nitroglycerin with infusorial

earth he obtained a controllable explosive that made gunpowder seem almost quiet and reserved, not to say bashful. Nitroglycerin is produced by treating glycerin with nitric and sulphuric acids. Mixed with infusorial earth or kieselguhr, as formerly, or latterly with wood pulp and ammonium nitrate, it is dynamite.

What happens when you wash your hands? You use soap, and with its help remove the dirt, but why does the dirt come off? Now, although this is a fair question it is by no means a simple one, but I shall give the best explanation that I can. In most soaps there remains some free alkali. This attacks the fats that ooze out in the perspiration and saponifies them. That is, it splits them into soap and glycerin. But in a theoretically perfect soap, which contains no free alkali and which, therefore, though slower in its action, is less likely to irritate the skin, we have the process which we must now try to explain.

Colloid chemistry, you may remember, has to do with the behavior of particles larger than molecules, but too small to be seen with the microscope in the best daylight, and these particles keep up a perpetual dance; they are constantly in motion from being

bombarded by the moving molecules of the surrounding fluid, no matter how still this stands. The surface of each colloidal particle seems to have a kind of skin, or protective quality, that keeps it from other colloidal particles, thus forming a clot. Milk, for instance, is colloidal stuff, and will curdle if you put vinegar or some other acid in it. That is, the acid destroys whatever protection there was to the surface of the minute casein particles, and so these particles come together and form clots, and the milk becomes, as we say, curdled. Before this the particles were small enough to be kept in suspension; kept so that they appeared to be dissolved, and yet by this action of the acid down they come in great masses as curds. What I want to bring out is that the substance which yielded a protecting surface to each of the particles before we put the vinegar into the milk, and thus destroyed the quality of it, did its job pretty well.

Soap is a colloid, and when we get a little of it in a great deal of water we have it in dispersion, which is the precise way of speaking of a colloid when it appears to be dissolved. The particles of dust and grease on your hands are clotted there and stuck

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on. Then, in washing, the colloidal particles of the soap, in their constant dance, wriggle around the particles of dust and the like, loosening them up and bringing them into a shaking or moving condition. Then, when you dip your hands in the water or let water run over them the dirt particles which have been pried and joggled loose slip off. This is not the explanation I made in *Everyman's Chemistry*, but I think it a better one.

The laundry business has become a great industry, and the national association of laundrymen has done very well in having its problems investigated at the Mellon Institute of Industrial Research at Pittsburgh. The more women work outside the houses in which they live the more washing must be done in laundries—unless we go dirty and wear soiled clothes, which is against the habits and ways of the times. If a man works twelve hours a day he is likely to be so tired when he gets home that all he wants is something to eat before he turns into bed. If he works eight hours a day he has some free time, and may want to go to a movie show, a lecture, concert, or to the theater, and for this he needs a clean shirt and collar. Or if he stays home he wants to clean up to please the wife. And all this means more

washing. Laundries are here to stay and to multiply.

What the soap does to the dirt on clothes is much the same as what it does to the dirt on the hands, except that the laundryman has a greater variety of soil to meet and conquer. Among the many substances to be removed from clothes are, roughly, albuminous substances, such as blood and egg stains. These are compounds of carbon, oxygen, hydrogen, and sometimes other elements, with nitrogen. Vegetable dyes which cause fruit and wine stains, fats and oils which include the petroleum bodies, acid and alkali stains, body excretions, and little particles of skin, old starch, street dirt, and soot, comprise most of the other things we want to remove. They are attached principally to cotton, flax or linen, wool and silk. They are colored with a wide variety of dyes which vary greatly in fastness to wash and to alkali. Silk and wool differ from cotton and flax, inasmuch as the latter are formed chiefly of cellulose. Both wool and silk contain nitrogen, and their fibers have a different chemical structure. Wool has to be carefully treated, because with alkali it mats or felts, and carelessness in this respect will spoil the quality of a beautiful piece of

woolen goods. On woolen and silk goods only an alkali-free soap should be used.

The woman with a wash-tub has one advantage over the laundryman. She washes and scrubs each garment till it is clean, then stops. The laundryman, after his goods are collected and marked, sorts them into lots of the same kind, but science has neglected as yet to provide him with a mechanical dirt indicator, so that all the articles in the same batch are washed for the same length of time. The goods go into the washing-machine, which consists of two cylinders, usually of wood, one inside the other. The outer cylinder is stationary, and is connected with water and steam pipes, also with the drain pipe. The inner cylinder, into which the clothes are put through a hinged opening, is perforated with little holes, so that the water reaches the same height in both receptacles, partly filling them. This inner cylinder is revolved and is equipped with an automatic reversing device, so that at short intervals its revolutions are changed. That is, first it goes around one way and then the other. This keeps the goods incessantly tumbling into the water and out again.

The chemical bodies used in this cleansing process differ according to the batch of goods,

and the goods are roughly divided as follows: white collars, cuffs, and shirts of either linen or cotton; colored cotton garments usually sorted as to colors; white fabrics other than shirts and collars; woolen goods; silks.

The following is a method of treating white cotton and linen goods: After the clothes have been put into the machine cold water is admitted and allowed to remain for about five minutes. This cold rinse, to which is sometimes added a little soda ash (soda ash is carbonate of soda), is useful in removing the loose dirt, but more especially in dissolving the albuminous substances. Albumen is contained in blood, in white of egg, and is found, in one form or another, in all living things. As an example let's take white of egg. This will dissolve or disperse in cold water, but, as everybody knows, if we heat the water it will clot into a white, cheese - like substance. Everybody knows hard boiled white of egg. Now in washing we do not want to fasten that kind of dirt on the clothes; we want to get it off. We should fasten it on if we started by boiling the clothes, and then have to work all the harder to get it off. Simple enough, isn't it?

After five minutes of cold rinse this process should be completed, and the water is

run off. Then comes the "first suds" proc-
ess, in which hot water is used and the soap
solution added. The quantity of soap and
other chemicals varies with the goods, but an
average would be ¾ per cent. soap and ¼
sodium carbonate (soda ash). For, say, 75
pounds of dry clothes thirty gallons of the
solution is needed. Since there are 8 pounds
of water in a gallon there would be 240 pounds
of water in 30 gallons. One per cent. of that
would be 2.4 pounds. A quarter of that would
be 0.6 pound, or somewhat less than nine
and a half ounces of soda ash, and ¾ would
be somewhat less than one pound, thirteen
ounces of soap. Steam from the boiler is
run in to keep the water up to about the
boiling-point, and the whole business is main-
tained for about twenty-five minutes. Then
it is well to rinse the clothes once more to get
out the dirty soap solution.

You see, despite the colloid theory of soap,
practice shows that more alkali is needed,
and as soda ash is a salt with a strong base
(sodium) and a weak acid (carbonic acid),
it has an alkaline way with it. Sometimes
soda ash and bicarbonate of soda are mixed.
Bicarbonate is not so strong, and more of it
is required to do the work, so that in theory
the same result is attained by using less of

the soda ash alone. I understand that this tendency prevails in the laundries which offer scientific practice and the best care of clothes, and in which, consequently, the best business is done in the long run. Borax, a very mild alkali, is also used, and so is caustic soda, one of the most powerful alkalis. It is a matter of quantity regulation. The dirt must come off, but the clothes must not be destroyed—that is, the fiber of the cloth must not be ruined.

Now we come to what is called the "second suds," in which the soap-and-alkali solution is generally made a little weaker than in the first. The bleach liquor is added along with the soap, and the operation lasts about twenty-five minutes, with the wheel moving all the time. Here is where the most damage is done. Bleaching powder was formerly used, but an improvement on this is sodium hypochlorite. In some laundries common salt is put into the bath, and through the solution an electric current is run which splits the salt into chlorine and sodium, the latter straightway becoming caustic soda. In one way or another chlorine seems to be the most practical bleaching agent, whether it be obtained from bleaching powder, sodium hypochlorite, by the elec-

trolysis of salt, or the direct addition of chlorine as such. It does bleach, but it also does eat into the fiber. Mr. W. F. Faragher, a well-known authority on the chemistry of laundering, tells in Rogers's *Manual of Industrial Chemistry* of some of his experiments. He laundered one series of collars with bleach, and a control series without bleach, and observed how they stood up. The bleached collars broke in seven to nine treatments in the laundry, while the unbleached stood twenty - five treatments. Threads which broke when a weight of 1,725 grams was attached to them, after being bleached twenty times, broke under a weight of only 100 grams. Chlorine certainly has teeth! But it is a great decolorizer. Ozone, which is a temporary condition into which small quantities of oxygen are transferred by a strong current of electricity (and which you can sometimes smell after a thunder-shower), is a bleaching agent, but it does not seem quite powerful enough. The same may be said of a number of other bodies. There is always room for hope, however, that a less harmful bleach may be developed. I know of a new one full of promise coming along, but I shall not say what it is, because it may turn out to be as much of a disappointment

as the others. One thing, however, is clear, that it behooves the laundryman to be miserly with his bleach. It is one of those things of which, when applied to our shirts and collars, we ask the very least and not the greatest measure of generosity.

The bleach (chlorine) gives to cotton and linen goods a yellowish tinge which is overcome by the action of dilute acid. Then, too, just as a little blue is put into white sugar to give it that quality of whiteness that we like, so in our clothes we want the kind of white produced by a little blue. Therefore, after the bleaching liquor is discharged, fresh water is run into the wheel, some laundry blue added, and there follows what is called the "acid rinse." Either acetic, oxalic, or lactic acid is used; all of them mild. In weak solutions these do not attack the fiber. The acid neutralizes any alkali left over, brings out the blue, and overcomes the yellow tinge. Now the clothes must again be rinsed, because, while a weak solution of acid does not injure the fiber, it causes serious harm if concentrated. It reduces the breaking strain and therefore the strength of the threads So, if we were to dry out the wet clothes as they now stand, the water would pass off, but the acid would remain on the material

and be strong enough to injure it. Therefore the laundryman rinses again, and sometimes a couple of times more.

Now the clothes are clean, and the next step is to dry them. The woman at the tub wrings them, but the laundryman has her beaten at this game. He puts them into a centrifugal extractor, which is as dangerous as a live wire. It is a round, metallic box, perforated, placed on a spindle so as to be revolved at great speed, and protected as it revolves by a cast-iron shell. A high-speed motor is connected with a pulley on the spindle, so that when the power is turned on that cheese-box inside begins to spin around and around until it runs up to about 2,000 revolutions per minute. The water is swished out through the holes, collected, and let out through a pipe leading from the bottom of the protecting shell to the drain. Fifteen or twenty minutes of this will make the goods ready for starching.

We shall not carry these white goods farther through the processes of starching, drying, and ironing. We shall only repeat that with wool and silk no alkali may be added to the soap bath, and a soap free from alkali should be used. Chlorine bleach must also be avoided, because, whether employed

as bleaching powder, or sodium hypochlorite, or in any other form, it not only weakens the fibers, but makes the fabric harsh. So milder bleaches must be used, such as peroxide of hydrogen, sodium perborate, or sodium hydrosulphite.

I have run the risk of talking too much about this subject just to show how chemistry touches it on every side. And the point I want to make is that while a man cannot study chemistry and then know, right off the bat, so to speak, how to run a laundry successfully, he makes a far better laundryman if he has a sense of chemistry. For instance, if his water is too hard he doesn't take it out in growling at it. He knows that when he puts the soap into hard water the lime and magnesia take the place of soda in combination with the fatty acids, thus making lime and magnesia soaps according to the degree of hardness of the water, which is the amount of these two minerals it contains. He knows that lime and magnesia soaps are insoluble, that they are sheer waste, that they make a nasty scum, and that hard water forces him to use much more soap than soft water, and messes up his wash. If he doesn't know how to treat the water before using he knows where to go to find out.

He isn't carried away by trade-marks, and what he buys he has analyses made if he can't make them. When he buys soap he does not want to pay for too much water in it, and the same may be said of starch. He learns how to use the microscope and to read the meanings of what he sees. He watches over the goods intrusted to him, and since he knows his materials he doesn't have as much trouble as his less-informed brother. His costs are lower, and his work is better, if he maintains chemical control. At the same time chemistry alone will not make him a good laundryman. He must know the technique of the trade if he would succeed.

THE EARTH AS RAW MATERIAL

CHEMICALLY speaking, limestone, chalk, and marble are substantially alike, being a salt having calcium (known in combination as lime) as the base, and carbonic acid as the acid. If you drop sulphuric acid upon a piece of marble or chalk or limestone you can see the bubbles of carbonic-acid gas, which is weak, being driven out by the stronger acid, and the production of calcium sulphate, or gypsum, in its place. The differences between the various forms of calcium carbonate are due to the size of the particles, the presence of water, and other bodies.

Magnesium is a metal very like calcium which we find in nature only in combination and not in a free state, and the two are often found in company in rocks.

Silicon, as I think we have said before, is also only found in combination. As the oxide it is sand. Sand and quartz are chemically

the same, except that quartz is likely to be purer. With water incorporated chemically with the oxide of silicon it becomes silicic acid, which may not be produced as such, but which goes into combination with other bodies of a basic nature. Thus, as the silicate of calcium, it is found in rocks, and silicate of aluminium is clay.

So it is combinations of these four metals with oxygen and water and carbon and with one another that constitute the chief part of the earth, including the mountains.

Now let's see what is made out of the earth:

Limestone or marble heated in a kiln gives off the carbonic-acid gas and becomes calcium oxide, which is quicklime or caustic lime. Magnesium behaves in a similar manner. Quicklime with water added becomes slacked lime, or calcium hydroxide, and this with water and sand forms mortar, or a kind of pudding which hardens as the water evaporates. Later the carbonic-acid gas in the air settles down and forms something like limestone out of the lime again, which is the reason why mortar improves with age, why old walls are stiffer than new ones.

Cement is a combination of calcium with silicon as a silicate—that is, a salt with calcium as the base, and silicic acid as the acid.

and also of lime with aluminium, in which the lime, being more basic than the aluminium, allows the alumina to act as an acid against it. The modern cement industry began along in 1845, when a bricklayer of Leeds, England, named Aspdin found that if he roasted Thames chalk (calcium carbonate) and Medway mud (or clay, aluminium silicate) and ground it and mixed it with water it would set. It looked like a stone familiar to those regions as "Portland stone," and so it was called Portland cement. Aspdin put on long robes and a pointed hat when he made his cement, claiming to do it by witchery, and he put all sorts of odds and ends into his kiln, talking a lot of gibberish which he called incantations. The only person unaffected by this was an inquisitive neighbor named Johnson, who got advice from a chemist in London, and experimented until he found out wherein the quality lay. Then Johnson proceeded to make cement and get rich, being an able business man. What happened to Aspdin in the end I never learned. I only know that the man who has not a good business head has no show in competition with the fellow who has a good business head. This has always been so, is now, and always will be. Selah!

If we take quicklime (unslacked) and heat it in an electric furnace with coke, and heat it up to the temperature of the electric arc, which is about as hot as sizzling sinners getting their reward, let us say, we have a combination of carbon with calcium known as calcium carbide. Then, if we put water on calcium carbide the oxygen of the water turns the calcium to calcium oxide, which is lime, and which more water straightway slacks, while the hydrogen combines with the carbon to make acetylene gas. And that is used for lighting.

Calcium phosphide is interesting. It is made by heating lime and red phosphorus to a high temperature in an inclosed vessel. When the reaction is complete it is a reddish brown crystalline substance. When thrown into water it decomposes instantly, producing a gas composed of phosphorus, oxygen, and hydrogen, on the one hand, and lime on the other. The gas catches fire as soon as it meets the air, burning to an oxide of phosphorus and steam, or water. It is used for signal fires at sea. About a pound of it is placed in the lower half of a tin can, the cover of which is then fastened on, making it air-tight. This is then attached to a float, a hole punched in the bottom and the top,

and thrown overboard. Water comes into the hole at the bottom while the gas escapes from the hole at the top and straightway burns for about an hour with a flame nine to eighteen inches high.

Sulphuric acid with lime forms calcium sulphate, or gypsum. This has various ways of crystallizing with more or less water, and in one form is known as plaster of Paris, which, by the addition of more water, will set. Natural gypsum of very fine texture and having a clear, partly transparent quality is called alabaster.

Sand and clay are also the raw materials for a great many industries. Silicon combined with oxygen is called silica, and as such it is sand and quartz, and is found in many rocks, especially in granite, where it may be easily seen. Now sand is the main raw material for glass, and here, curiously enough, comes a use for phosgene, one of the poison gases introduced into warfare by the Germans. Sand is usually made brown by the presence of a certain iron oxide, and phosgene dissolves this out. It would be a good thing if we could make glass of pure silica, but it takes such an infernal heat to melt it that it is not practical, except for chemical apparatus. Glass, however, is sand

or silica melted up with the oxides of two or more metals. Soda makes silica very easy to melt, too easy, in fact, to make good glass, for pure silicate of soda is very soluble. Lime also is added, and the soda-lime glass, as it is called, is in most general use. But the field of glass industry is too big for us to discuss in detail and keep within the required size of this book. Glass is not a true chemical combination. In a true chemical combination the proportions of each element are fixed and definite. Glass is like a solution; the ingredients may be as varied as you please. In fact, scientifically speaking, glass is called a solid solution.

There is a clay found in Georgia and Alabama, and also in France, called bauxite, that contains a large proportion of the oxide of aluminium known as alumina. This by heat treatment in a powerful electric arc enables the metal aluminium—or aluminum, as it is called—to be put upon the market for general use. This remarkably light metal is coming always into greater use, for electrical conductors, for household utensils, and for the production of light machinery. It may be mixed with the metal magnesium and made lighter still, and as the airplane industry grows more of it is likely to be

called for. Some day we may be able to get the metal aluminium out of ordinary clay, but we can't do it economically yet.

Clay, mainly aluminium silicate, has the property of being soft and molded into any shape when wet, but when water is driven out, not only from the outside of the particles, but out of chemical combination with them, then it becomes one of the most indestructible of substances. Heat will not affect it save at high temperature, and it will not take on water again. Its great trouble is that it is brittle and will break, as every house-wife knows of her earthenware pots and dishes. Of course there are a great many kinds of clay, differing in the conditions under which, in the history of the earth, they have arrived at their present state. They have different impurities and are in different forms, but most of them are composed prin-cipally of aluminium silicate.

In making brick the clay, after being dug, is usually allowed to weather, and then, after mixing, to get the desired clays together in pits or mills, they are molded, and sometimes pressed in steel frames and then baked.

Tableware is made by molding the proper clays by hand on revolving tables or in molds and baking the forms first to what is called

a biscuit. Then they are glazed by dipping them into a preparation consisting of a mixture that turns into a kind of glass when the articles are baked or fired again. The uses to which clay is put are very numerous, owing to the permanent quality it possesses after heat treatment—always providing it doesn't get broken. A partial list of these uses is porcelain, table ware, cooking vessels, majolica stoves, polishing-brick, all kind of building-brick, terra-cotta, all kinds of tile, firebrick and crucibles to withstand great heat, cement and all things made of it from railway ballast to ships—and surely a thousand other things, including, I regret to say, an occasional use to adulterate food.

XI

IRON AND STEEL

IRON is by no means so common on the surface of the earth as silicon, aluminium, or calcium, but it is, nevertheless, very widespread. Observe, please, I said *surface* of the earth. From the magnetism of the earth it is possible that its interior, of which we know nothing with certainty, is a huge iron ball. There is no trouble in sight about the supply of iron, anyway, no matter what the interior of the earth may contain.

Iron has some very important chemical properties: it will oxidize or rust, in damp air, but the oxides are reduced—that is, the oxygen is driven out of combination and the metal set free at temperatures above 260° Centigrade, which is 500° by our Fahrenheit thermometer. Its other important properties are its strength, its magnetism, and its ability to retain a good cutting edge after it has been properly treated. In these respects it is supreme. Add to this its cheap-

ness, and we can well understand its great value to mankind. Then, too, as Bradley Stoughton says, iron can be made one of the strongest or one of the weakest of metals; one of the hardest or one of the softest; one of the toughest or one of the most brittle. It may expand and contract, with changes in temperature, from a slight alteration to a great deal, and it may receive such of these qualities as are desired of it, almost at the will of the chemist who has the preparation of it in charge. And most of these variations are brought about by a change of less than 5 per cent. in the constitution of the mass, or by different heat treatments.

The chief ores are oxides of iron, combinations of iron, and oxygen. Mixed with these are various kinds of rock, many of which are silicates of one sort or another. For practical purposes from 35 to 45 per cent. of iron, at least, is needed in the ore. Another iron ore is known as pyrites, and is a combination of iron and sulphur. This is used first by the sulphuric-acid manufacturers, who roast the sulphur out, leaving the remaining iron, in the form of oxides, available for smelting.

The ore is put into the blast furnace, where it is smelted with heated air, with coke, and

a flux, usually limestone. In other words, there is the iron ore with the iron and a lot of silica or silicates in it that are hard to melt. The flux, or limestone, makes a kind of glass which melts more easily, and which, while molten, acts as a means to carry off the various bodies other than iron as slag. The iron, however, was in combination with oxygen, and the coke, at that great heat, picks up the oxygen and escapes in part as carbonic-acid gas, the molecule of which contains an atom of carbon with two atoms of oxygen, and in part as carbon monoxide, the molecule of which consists of one atom of carbon and one of oxygen. This poisonous carbon monoxide is also known as "producer gas," and can be burned in the air to carbonic-acid gas. Remember this for a minute, please.

The operation of the blast furnace goes on, day and night, without any shut-down, because the furnace must not be allowed to cool. The molten iron collects on the hearth at the bottom of the furnace, and on the top of the iron the slag, also molten, floats. About fifteen times every twenty-four hours the furnace is tapped for the slag to run off, turning into a hard, glassy rock as it grows cool. About six times in a day

of twenty-four hours the iron is tapped, being either run into molds or carried, still molten and white-hot, for further treatment, to be converted into steel. The molds into which the iron runs are called pigs, and the iron is known as pig iron. It is not pure iron; it contains $3\frac{1}{2}$ to $4\frac{1}{2}$ per cent. of carbon, and varying amounts of sulphur, silicon, and other elements. The slag is useful for filling, for railway ballast, and also as raw material for the manufacture of cement.

The gas which escapes at the top contains 22 to 27 per cent. of carbon monoxide, and about one-third of that produced is used to run steam boilers for engines, or to run gas-engines to blow the air into the furnace. The rest of it is available to generate power.

Wrought iron is made by hand, the process being called puddling. In very much smaller furnaces pig iron is melted on a bed of iron ore. The ore gives up its oxygen, and some iron is reduced from it, and at the end of about one and a half hours of repeated working or puddling the carbon, silicon, and manganese are almost entirely carried away, as well as most of the phosphorus and sulphur. The iron is drawn from the furnace in a pasty state, because the purer the iron the more heat is required to melt it, and in the heat

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of these furnaces it grows more pasty as it grows purer. Mixed with it are little webs and strings of slag, which are drawn out by rolling, and which give the metal the quality of containing long fibers.

The difference between iron and steel is not simple. Pig iron is likely to contain carbon free in the form of graphite, mixed with it, but not chemically combined with the iron. The combinations of carbon with the various metals, the so-called carbides, are generally hard, and so the more carbon we have in chemical combination with the iron the harder it is likely to be. Pig iron is too impure to be called steel, anyway, and as it lacks the strength of steel, owing to the absence of iron carbides. Wrought iron contains very little carbon, and therefore lacks the strength of steel and cannot be made to take a temper.

Now if we melt wrought iron in a crucible with charcoal, pig iron, or some other substance rich in iron, the resulting metal will contain $\frac{3}{4}$ to $1\frac{1}{2}$ per cent. carbon, and this is the well-known crucible steel used in cutlery, etc. This is the oldest way of making steel.

Bessemer steel is made by blowing air through molten pig iron in what is known

as a converter. The oxygen of the air combines with the silicon, manganese, and free carbon, the carbon going out as carbonic-acid gas, and the remaining substances separating out as slag. When the "blow" is about at an end the desired amount of carbon is added, which goes into combination, and the result is the cheapest steel, but not the best.

Open-hearth steel is made by boiling steel scrap and pig iron, and sometimes some iron ore, in a shallow container or hearth, the burning gases striking the mass on the top. This takes nearly as many hours to make a large batch of steel (50 to 250 tons) as the Bessemer process requires minutes for a smaller lot (say 10 to 20 tons), but the quality is generally better. Later practice provides economy in the duplex process, whereby the iron is first blown in Bessemer converters and then boiled in open hearths for a shorter time.

Electric steel is the latest method whereby the steel is heated, and the required ingredients added in an electric furnace. This provides a very fine quality of steel, similar to that made in crucibles, and for many purposes it has supplanted crucible steel. To save the expensive reheating it is sometimes produced by the triplex, or threefold, process

of running it in a molten state from the blast furnace into Bessemer converters, then into open hearths, and finally into electric furnaces.

Now we have talked a little of the very outside of the chemistry of some things that are familiar to us, and if you have found it interesting, and feel that you would like to get closer to the subject, the way to do so is to read some more. Whether it will be worth your while to read another book of mine, called *Everyman's Chemistry* (Harper & Brothers), which is longer than this, is open to question. I tried to make it an introduction to the subject for those who know nothing about it when they take the book up. To read it will not make a chemist of you; it will only open up the chemical aspect of things more than this does. If you need to get right into the subject I suggest either of two good books, which you must choose according to your temperament: Alexander Smith's *Inorganic Chemistry* (The Century Co.) is an excellent text-book. It states the facts clearly and well. It does not use any unnecessary words, and it is designed for use in colleges. *Modern Inorganic Chemistry*, by J. W. Mellor (Longmans, Green & Co.), is longer and more discursive, written more as though Professor

Mellor were talking to you. It goes into the theory of chemistry, and, while it is not easy reading, it is delightful reading. If you can read Mellor, and enjoy it, keeping the general principles in memory, you will have made a good start. There is no use in trying to remember all the detailed facts; these are always to be found in books. It is the general principles, however, that we must know. After finishing Mellor or Smith, if you take up a little book called *Introduction to Qualitative Analysis*, Part I, Theoretical, by Prof. Julius Stieglitz, of the University of Chicago (The Century Co.), and can digest that, you will get the real chemical idea of things. Then if you want to go into organic chemistry you will know enough to go ahead in the way best suited to you.

All this provides for chemical thinking, rather than chemical work. The laboratory is the place where things are done and where secrets are discovered. That is like a trade, and it is just as complex a matter as learning a trade. It calls for deft fingers and the mechanical instinct. Some great chemists are remarkable craftsmen, and can construct almost any kind of an apparatus out of glass, cork, and rubber to serve their purposes. The late Sir William Ramsay, who

discovered gases in the air that never had been recognized before, was one of them. He could do almost anything with his fingers. Other great chemists have brilliant ideas, but have to depend on assistants to work out their problems, just as some great mathematicians can't add or subtract correctly. There is quite a call for laboratory helpers, and these often learn to make routine analyses with remarkable precision. If a man who has such a job is built for chemistry, of course he will study on the side and become a real chemist instead of merely a laboratory worker. He would have to do that to make his job interesting.

And, after all, that is the most important part of a man's working life—that his job shall be interesting to him. Unless it is, he is hardly likely to be good enough at it for it to pay him well.

And whatever the pay is, it makes all the difference in the world to him whether or not he likes his day's work!

THE END